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Features of combining of scanning probe microscopy with optical and scanning electron microscopy

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There are two main experimental approaches to visualizing the structure or mapping the properties of objects with nanometer spatial resolution. In one case, a focused beam of particles or radiation interacts with the sample under study. In this case, the beam source is far from the sample, while in another case a sharp solid-state probe close to the surface under study interacts with the sample. Since the interaction of focused beams and sharp probes with the sample surface has a different nature, the combination of beam and probe approaches in one device [1-5] provides more complete information about the object under research. The report discusses the features of combining a scanning probe microscope (SPM) with an optical (OM) or scanning electron microscope (SEM).

The requirements for compatibility of SPM with OM and SEM are discussed. It is shown that when a piezo-inertial displacement systems will be used a sufficiently compact SPM units, easily compatible both with the OM lens and the SEM goniometer may be created. The compact design of the piezo-inertial movers is due to the absence of complicated mechanical components and the possibility to easy controlled a piezo-inertial mover by asymmetric pulses of electrical voltage. In addition, to simplify the design and reduce the size of the SPM units, we used as a probe sensor the piezoresonance and piezoresistive cantilevers, which, unlike standard cantilevers, do not require an optical scheme to measure their deflection. The peculiarities of working of piezoresonance and piezoresistive cantilevers are discussed.

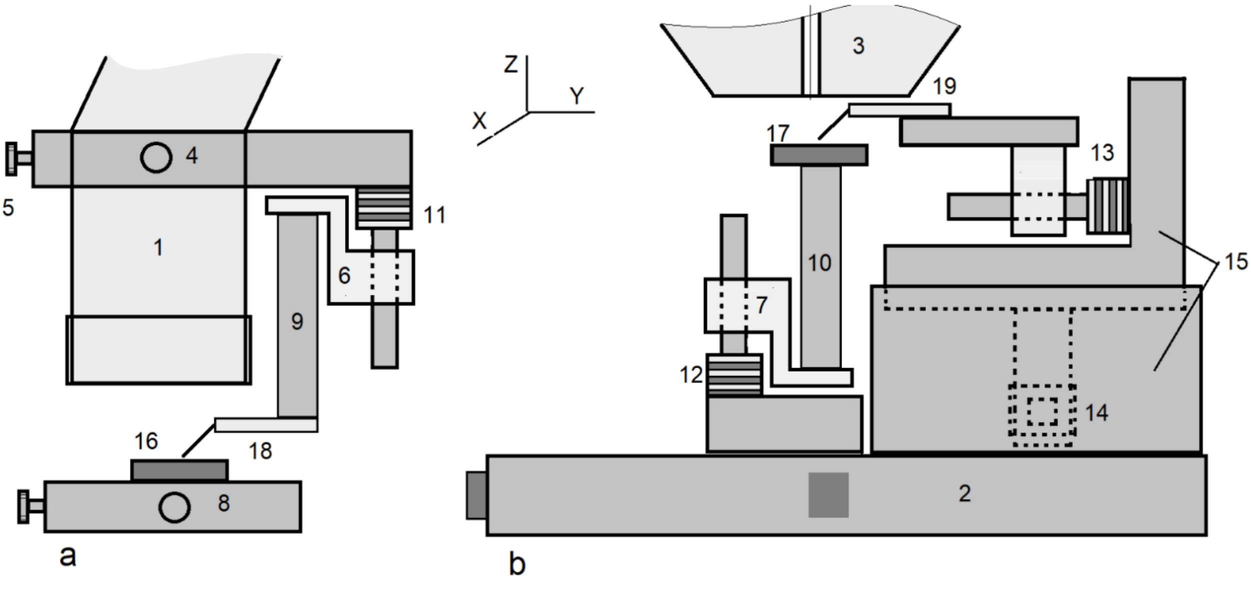

Figure 1. The scheme of SPM combination with optical microscope (a) and with scanning electron microscope (b). 1 – optical lens; 2 – SEM goniometer; 3 – pole piece of the SEM objective lens; 4,5 – screws for alignment of the probe under the optical beam; 6,7 – 1D piezo-inertial movers; 8 – 2D stage of OM; 9,10 – piezotubes for X, Y- scanning by the probe (sample); 11,12,13,14 – stack multilayer piezo actuators; 15 – 2D piezo-inertial mover; 16,17 – samples; 18,19 – probe sensors.

Figure 1a shows a scheme of SPM unit combined with the OM lens (1). Figure 1b shows a scheme of the SPM unit located on the goniometer (2) of the SEM under the pole piece (3) of the SEM objective electron lens. The gap between sample surface and the pole piece of the objective lens is 7 mm. In the case of a combination of SPM-OM the probe (18) moves in the (X,Y) plane under the OM light beam using screws (4,5). It is sufficient to use only 1D piezo-inertial mover (6) to capture the interaction between the probe (18) and the sample (16). To choose the place on the sample (16) a 2D OM stage (8) is used. The piezotube (9) is used for scanning by the probe

(18) at X,Y directions. The stack multilayer piezo actuator (11) is used both for fine scanning by the probe (18) at Z direction and for coarse approach of the probe (18) to the sample (16) using the 1D piezo-inertial mover (6). In the case of a SPM-SEM combination, a 2D piezo-inertial mover (15) is used to move the probe (19) under the electron beam. To select a region on the sample (19) surface the SEM goniometer (2) is used. In this case, the piezotube (10) is used to scan the sample (17) at the X,Y directions, and the stack multilayer piezo actuator (12) is used both for fine scanning the sample (17) at the Z direction and for coarse approach of the sample (17) to the probe (19) using the 1D piezo-inertial mover (7).

The performance data of the 1D and 2D piezo-inertial movers are given. The combinations of SPM with OM and SEM at the different measurement modes are discussed. Examples of visualization of objects of different nature by methods of beam and probe microscopy in combined systems SPM-OM and SPM-SEM, as well as an examples of probe nanolithography performed under the control of SEM are given (Fig. 2).

Figure 2. SEM image of a result of a dynamic force nanolithography performed under electron beam control in SPM combined with SEM. (on the left the W-probe used for probe nanolithography is seen, scanning area 6×7 μm^2).

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